Analysis of Candidate Communication Architectures for TAMDAR Implementation in 2007-2015

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Outline

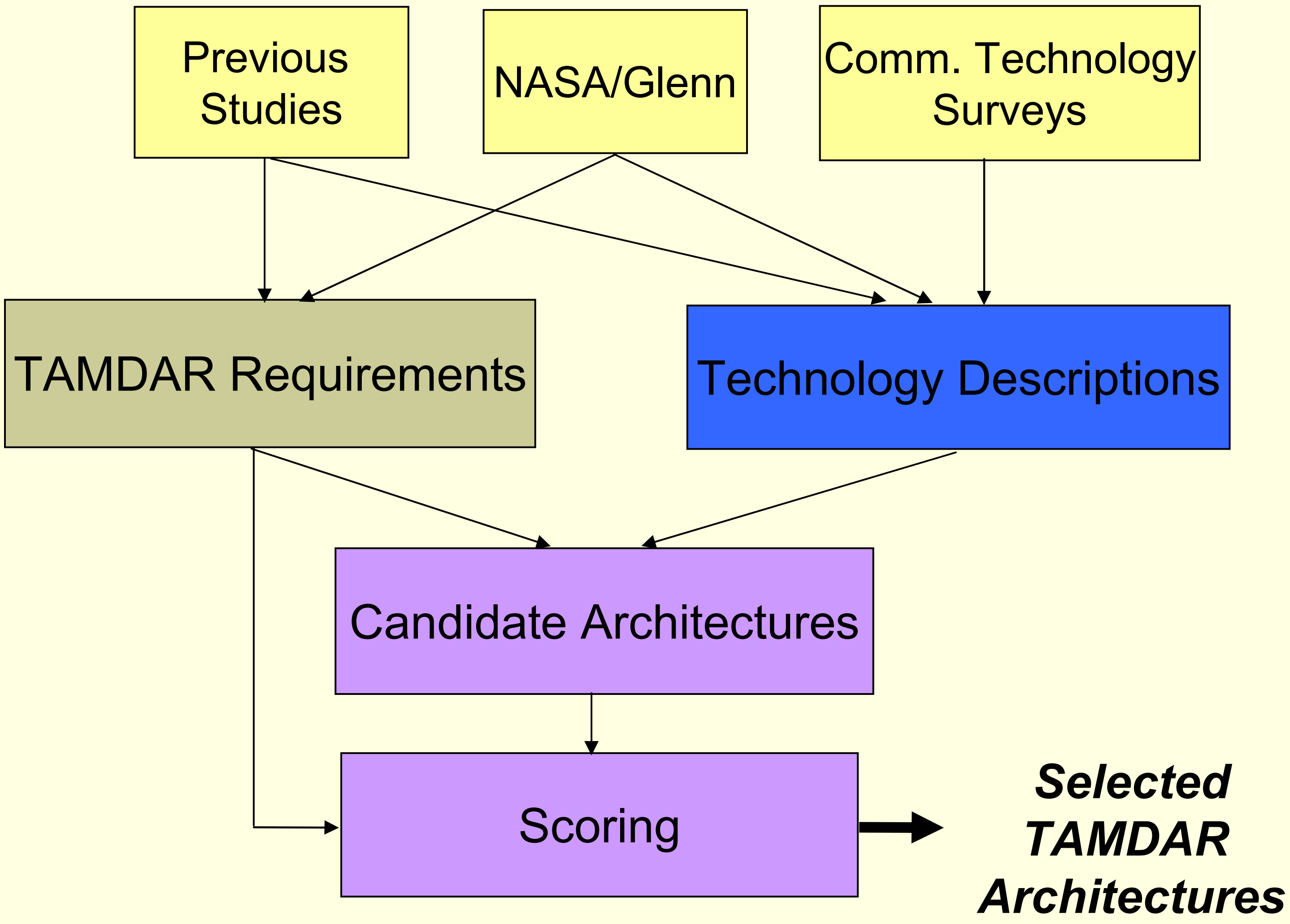
- TAMDAR Mission
- Architecture Analysis Process
- Data Link Requirements
- Analysis Methods
- Architectures & Standouts
- Summary

Tropospheric
Airborne
Meteorological
DAta
Reporting

TAMDAR Mission

- TAMDAR enables meteorological data collection from aircraft
  - Improving weather forecast models
  - Hazard alerts to nearby airborne users
- Targeted implementation onboard GA/regional aircraft
  - Complements other systems like Meteorological Data Collection and Reporting Service (MDCRS) on larger aircraft
  - Content: wind, temperature, moisture, turbulence, icing, etc.\
- Focus of architecture study is on communications / datalink capabilities
  - Long term deployment (circa 2015) is a goal of the study

Architecture Analysis Process



TAMDAR Requirements

- Requirements were examined in the following areas:
  - Channel Capacity
    - Air-Ground
    - Air-Air
  - Coverage
  - Latency
  - Cost
  - Others
    - Platform Constraints, Spectrum, Infrastructure
- Various sources were used to derive estimates for requirements

Req: Capacity – TAMDAR Message

- Capacity is based on message size and frequency of transmission
- Data fields developed by NASA/Glenn
- Overhead (20%) is added to account for framing, error detection, reserve content, etc.
- Estimated message size is 250 bits

Data Fields – Bits	Data Fields - Bits
General ID – 16 Aircraft Type – 8 Date – 16 Time – 20 Roll Angle – 4 Phase of Flight –4	Wind Speed – 8 Direction – 8 Temperature – 12 Water Humidity – 8 Liquid Vapor Mix Ratio – 8 Peak Liq. H20 – 8 Ave. Liq. H20 – 8 Super Cooled Large Droplet –4 Icing – 4
Position Latitude – 20 Longitude – 20 Baro. Altitude – 16	
Turbulence Average – 8 Peak – 8	**Data Collection Bit Total** **208**

Req: Air-Ground Capacity

- Frequency of transmission is based on DO-252 (AUTOMET MIS) estimates
  - Takeoff: 1 report per 6 seconds
  - Climb/Descent: 1 report per 60 seconds
  - Cruise: 1 report per 180 seconds
- *Average* Capacity is then estimated using a 250 bit message:
  - Takeoff: 42 bps
  - Climb/Descent: 4.2 bps
  - Cruise: 1.4 bps (4.2 bps due to latency req.)

Req: Air-Air Capacity

- Requirement for Air-to-air capacity (at receiver) is difficult to estimate
  - Requires assumptions about the "radius of interest" for TAMDAR reports & estimates of equipped air traffic within this volume
  - Communications and processing complexity to support air-air transfer is significantly higher than a pure downlink configuration
  - May enhance business case for TAMDAR adoption
- Based on estimates of the number of aircraft in the radius of interest (about 100 NM) in each flight phase, an aggregate capacity is estimated at 2-3 kbps

Req: Coverage & Latency

- Air-Ground Coverage
  - Complete or near-complete CONUS coverage
- Air-Air Coverage
  - 100 NM radius around TAMDAR transmitter used as strawman assumption
- Latency
  - Data received in 1-minute or less after time of measurement
  - Latency affects instantaneous capacity of cruise phase

Req: Cost

- TAMDAR is a more complex business case than other weather data in cockpit. Benefit to TAMDAR-equipped aircraft in-flight:
  - Hazard warnings
  - Real-time validation of weather information / forecasts
- Old Dominion University TAMDAR study
  - 67% of pilots would pay less than $2000 for TAMDAR system and only 17% would pay more than $4000 (NRE)
  - Assume minimum recurring cost; subsidies may be a potential means of supporting capability
- Desirable to augment existing communication system with additional TAMDAR functionality
- NASA GRC suggested using $1000 as Cost requirement

Req: Implementation

- “Implementation” requirements are significant, however in the long term, potential issues can be mitigated
- Platform Constraints – system must be able to be equipped on aircraft
- Spectrum – frequency allocation in US
- Infrastructure - needed for collection of TAMDAR reports at national repository (NOAA/NWS)
  - Terrestrial LOS systems would require an infrastructure with terrestrial network connectivity to be viable
  - SATCOM systems may support direct feed to a national repository

Requirements Summary

Air-Ground Capacity	transmit: 4.2 bps - 42 bps
Air-Air Capacity	transmit: 4.2 bps - 42 bps receive: ~2-3 kbps
Coverage	CONUS (air-ground) 100 NM radius (air-air)
Latency	≤ one minute
Cost	Under $1000 NRE; min. recurring
Platform Constraints	GA aircraft installations
Spectrum	Allocated spectrum for aviation
Infrastructure	Receiver network & support data transfer to CONUS repository

Analysis Methods (1 of 2)

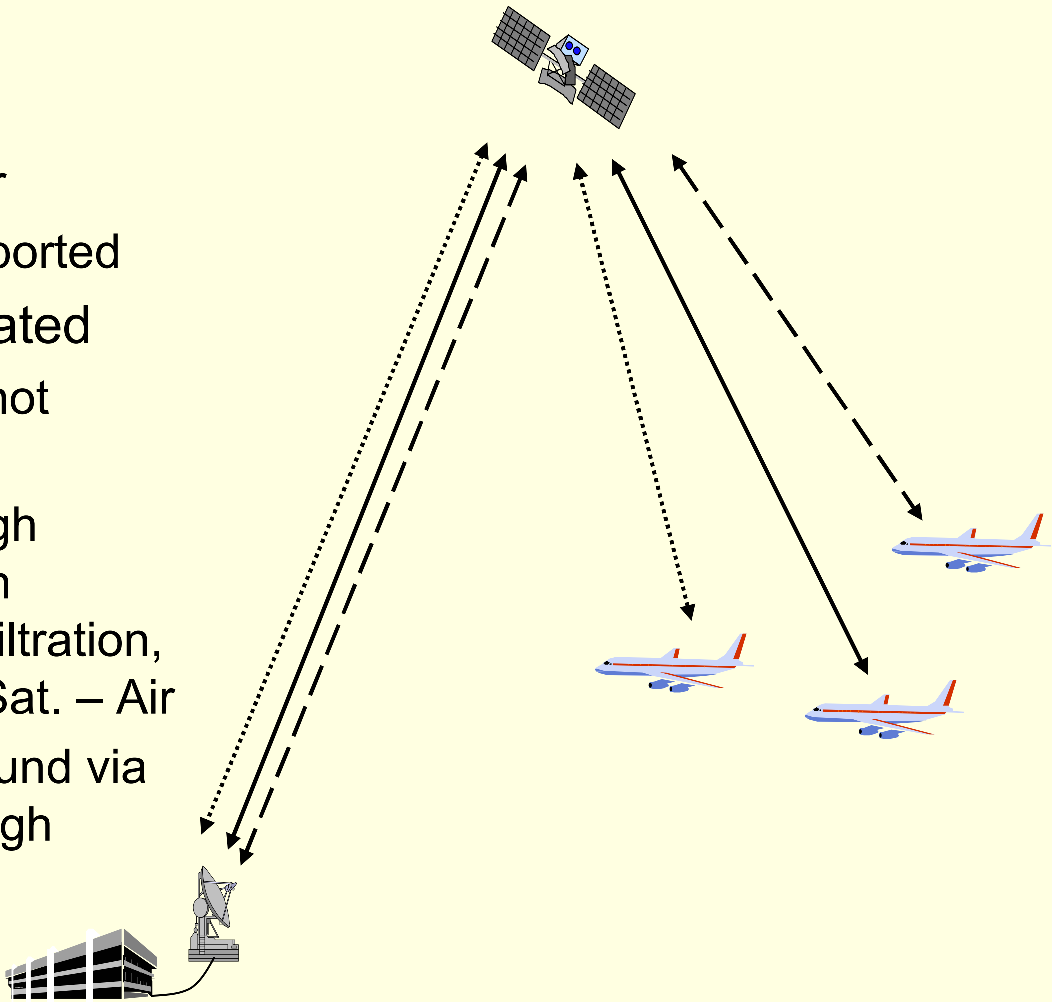
- Previous TAMDAR Architecture study focused on 2003 implementation
- Classes of systems had been identified
  - SATCOM
  - Terrestrial Based
    - Broadcast
    - Cellular
    - Addressable
- General characteristics of each architecture class emerged from that analysis

Analysis Methods (2 of 2)

- For each system:
  - Air-to-Ground Capacity is treated as first-pass threshold requirements
  - Other requirements scored to provide gradations
- All systems would require system engineering and optimization to host TAMDAR functionality

Satellite (1 of 2)

- Architecture is limited by air-to-air transfer
- Style 1: Point to point
  - E.g. Air – Satellite – Air
  - High capacity, but supported
- Style 2: Ground coordinated
  - Lower bandwidth, but not developed currently
  - Signal is passed through ground station between satellite broadcast for filtration, e.g. Air- Sat. – Gnd – Sat. – Air
  - Hybrid satellite, air-ground via downlink + air-air through ground rebroadcast
- Many systems analyzed

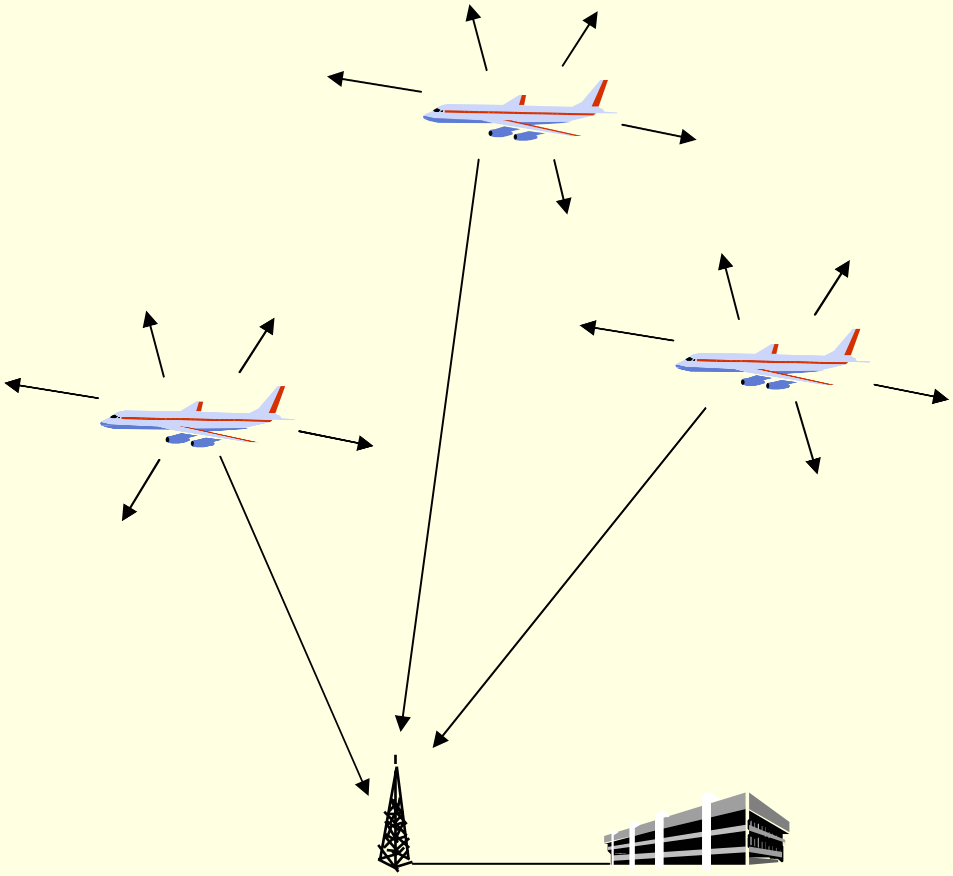


Satellite (2 of 2)

- Strengths
  - Air-Ground capacity is easily satisfied
  - Coverage is better than terrestrial systems + easily expandable
- Weaknesses
  - Air-air transfer is a challenge
  - Cost of SATCOM receivers on aircraft relatively high
  - In certain SATCOM systems, latency is an issue –
    - Store-and-forward systems are not likely to satisfy capacity/latency requirements
  - Aviation platforms limited at the current time
  - SATCOM systems are inherently volatile (cost, maintenance, etc…)
- Standouts : Iridium & Globalstar
  - Lower cost & current aviation platforms

Terrestrial: Broadcast (1 of 2)

- Systems considered:
  - VDL Mode 4
  - 1090 Extended Squitter
  - UAT
  - GATElink
- Strengths
  - Air-Ground & Air-Air capacity requirements are easily satisfied
  - Low Latency

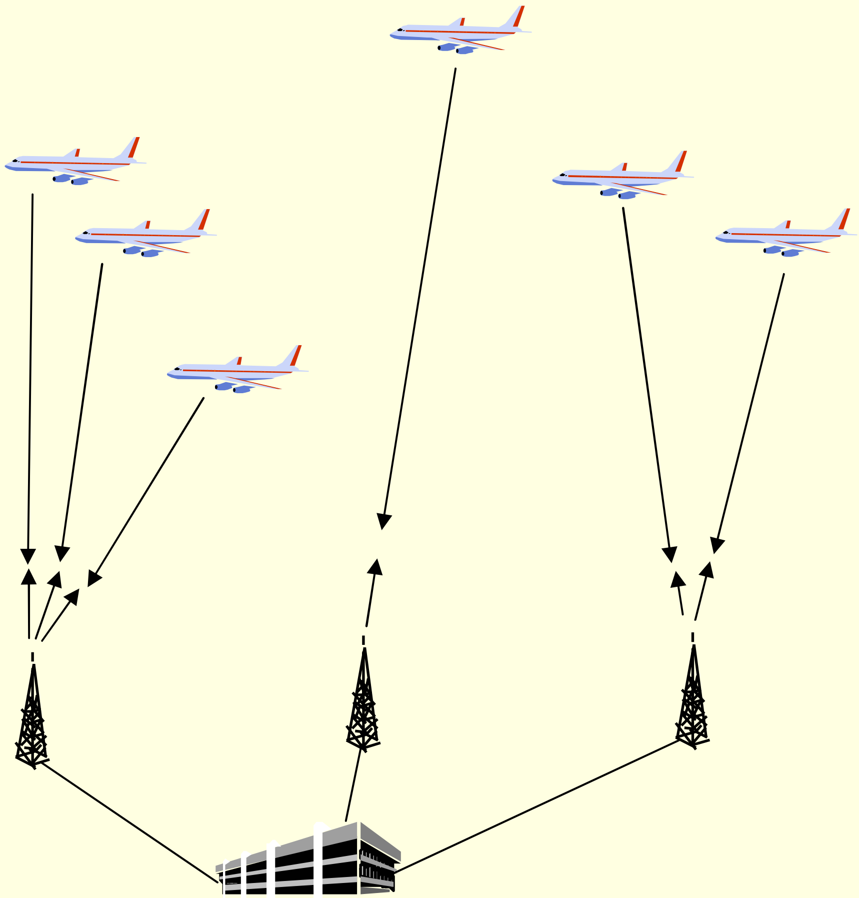


Terrestrial: Broadcast (2 of 2)

- Weaknesses
  - Coverage limited by line-of-sight - many ground stations to achieve CONUS coverage
  - Cost of infrastructure and receivers on aircraft a potential issue
- Standouts : UAT
  - FAA sponsored deployment of ADS-B infrastructure
  - UAT targeted for GA / regional users

Terrestrial: Cellular (1 of 2)

- Different architecture to support air-air transfer
  - Point to point
  - Ground rebroadcast
- Systems considered
  - Aircell
  - MagnaStar
  - 3G/4G cellular
  - Mobitex

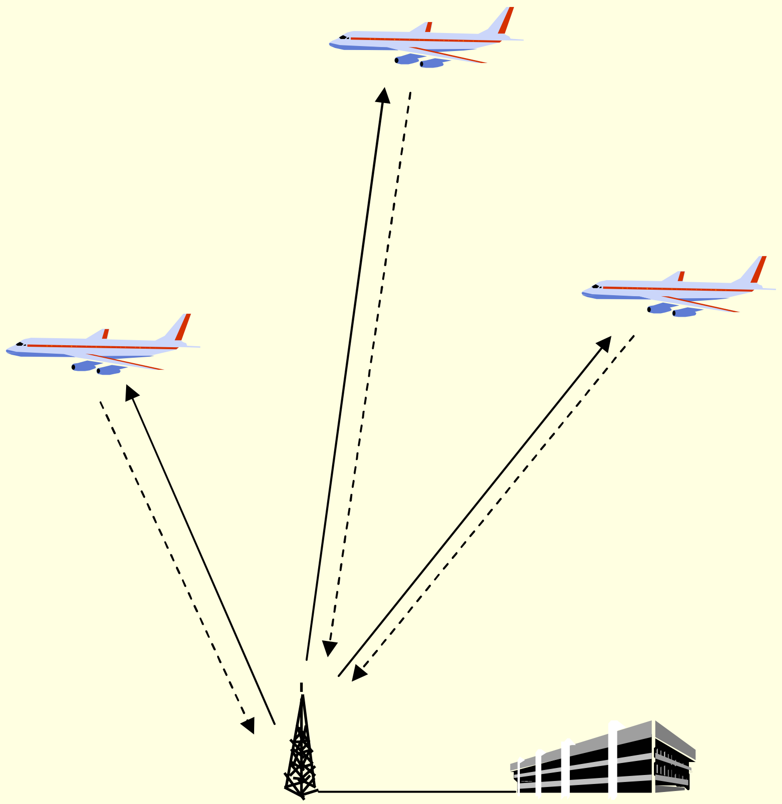


Terrestrial: Cellular (2 of 2)

- Strengths
  - Air-Ground capacity is easily satisfied
  - Massive infrastructure throughout CONUS provides coverage and cost-benefit
- Weaknesses
  - Air-air messaging is a challenge
  - Interference with ground-based systems
  - Issues with augmenting a deployed system
  - Aviation platform issues
- Standouts : AirCell
  - Aviation platform issues are solved
  - Cross-polarization to reduce interference with ground systems
  - Cooperative agreement with cellular providers

Terrestrial: Addressable (1 of 2)

- Systems considered
  - VDL Mode 2
  - VDL Mode 3
  - ACARS
  - AAN
  - HFDL
  - 802.11 Wireless Links



Terrestrial: Addressable (2 of 2)

- Strengths
  - Air-Ground capacity is easily satisfied
  - Aviation platforms well established
- Weaknesses
  - Air-air messaging is a challenge
    - Broadcast Mode may mitigate issue
  - Traffic loading can be high
- Standouts : Mode S
  - Broadcast mode for air-air communications

Standout Scores for Each Class

Requirement	Globalstar	UAT	AirCell	Mode S
Air-Air Capacity	0	2	0	1
Coverage	2	1	2	1
Latency	1	2	1	1
Cost	1	0	1	1
Other Issues	2	2	2	1
Total	6	7	6	5
Ave. Class Score	4	5	3	3

Scoring Key

2 : System supports requirement with substantial margin

1 : System can support requirement

0 : Information obtained is currently inadequate to score

–1: System does not meet requirement

Findings

- Some TAMDAR requirements are easily satisfied – almost all datalinks can meet these
  - Air-ground capacity and Latency
- Several requirements are not easily satisfied – greatly limits datalink options
  - Cost and Air-air capacity
- Most preferable TAMDAR datalink system is one of the standout LOS systems: UAT, AirCell, Mode S
- Hybrid solution (e.g. LOS + SATCOM, SDR) possible in future, not currently a realistic option